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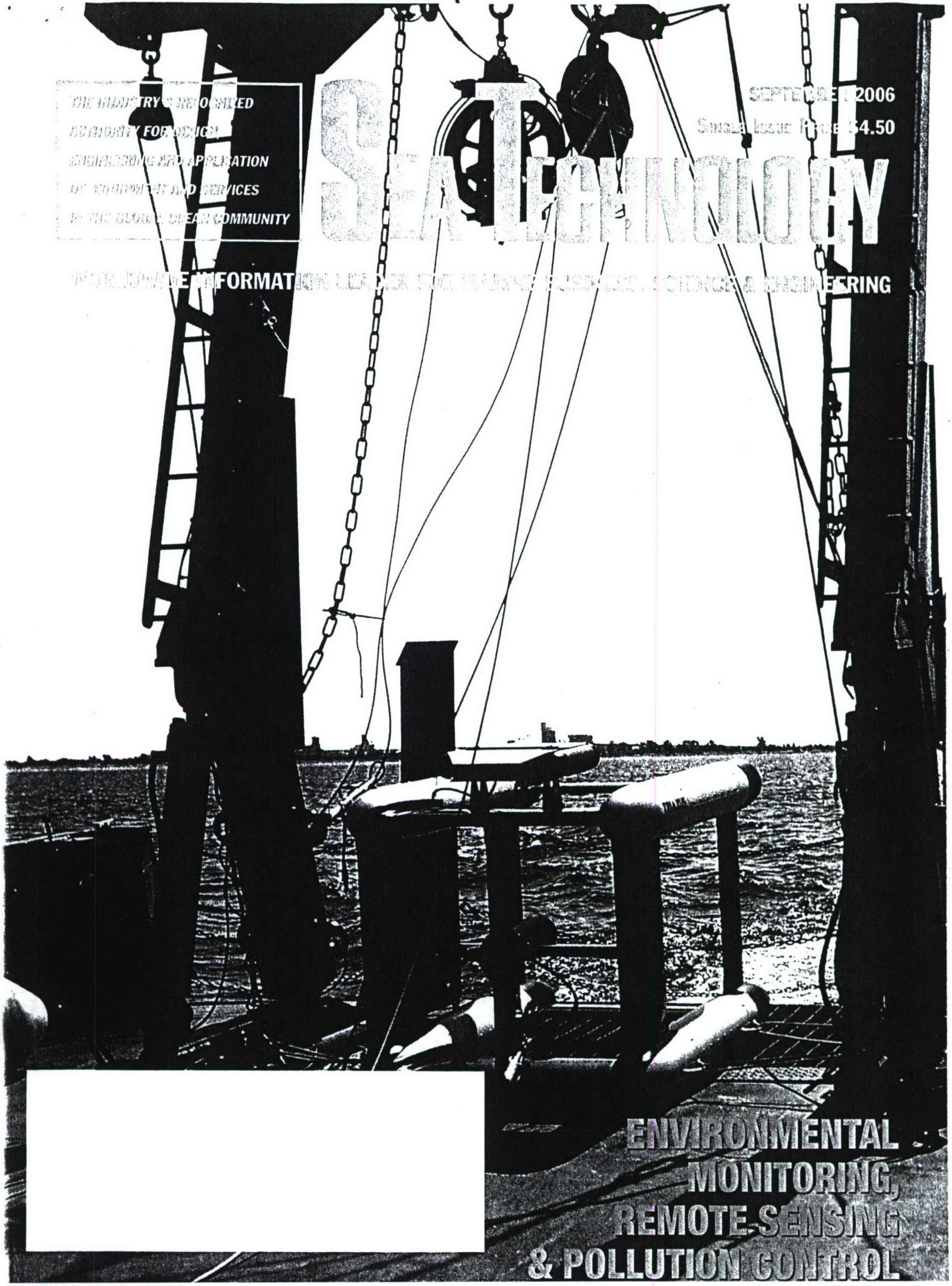

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COVER—This photo was taken onboard the University of Minnesota's R/V *Blue Heron*. The ship, on Lake Superior, was heading for sea trials of a Triaxus remotely operated towed vehicle system, with a complete deck handling system that included a winch, tow cable, deck cables and an overboarding sheave. The system will be used in conjunction with existing equipment for making high-resolution 3D surveys of temperature, salinity, transparency, phytoplankton concentration and current in the Great Lakes. The winch and Triaxus were developed by the MacArtney Underwater Technology Group (Esbjerg, Denmark). (Photo courtesy of Hans-Jorgen Hansen.)

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Airborne Remote Sensing of the Plata Plume Using STARRS

A New Generation Microwave Radiometer System Maps Salinity Off the South American Atlantic Coast

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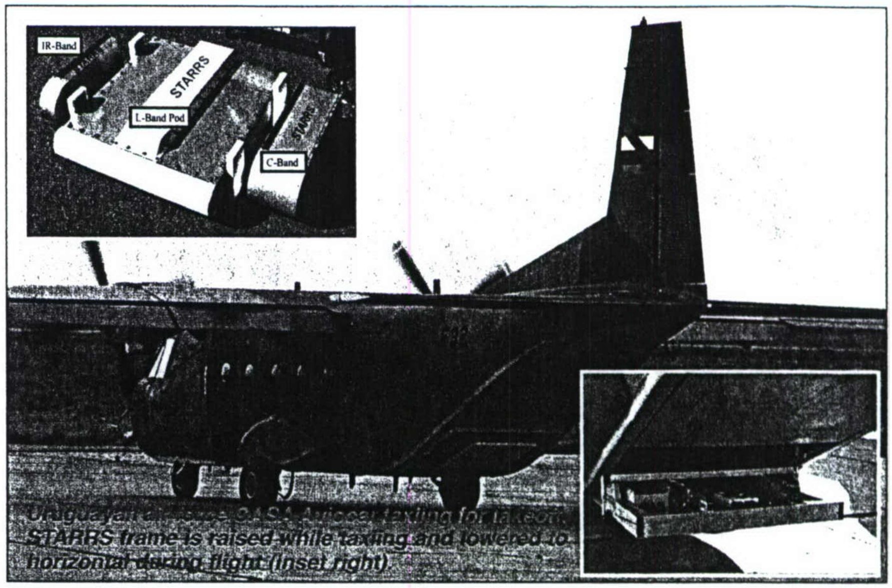


Uruguayan air force CASA Aviocar taxiing for takeoff. STARRS frame is raised while taxiing and lowered to horizontal during flight (inset right).

The characteristics of plumes discharging from major rivers into the coastal oceans reflect river basin properties and processes, and significantly impact continental shelf circulation and associated marine ecosystems. An international project, La Plata, was undertaken within the South American Climate Change Consortium framework to assess the behavior of the Rio de la Plata and Patos Lagoon plumes and their effects on the dynamics of continental shelf waters. The project involved scientists and institutions from Argentina, Brazil, Uruguay and the United States, combining ship and aerial surveys spanning the region between Mar del Plata, Argentina (latitude 39° S), and Itajaí, Brazil (27° S).

The objective was to study the seasonal behavior of the Plata River and Patos Lagoon plumes by obtaining comprehensive measurements of physical, chemical and biological fields in summer and winter.

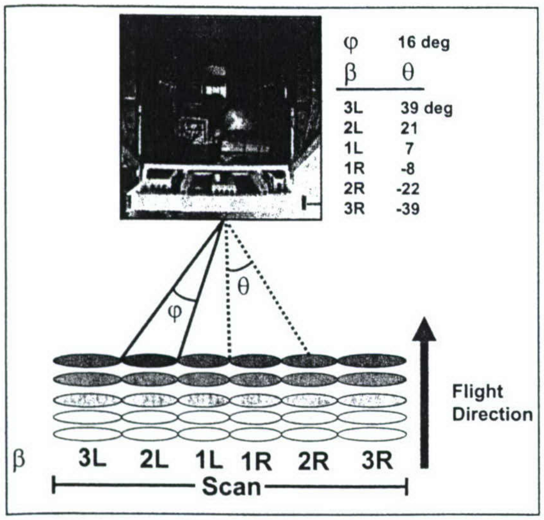
An oceanographic and remote sensing data set was acquired to provide a quasi-synoptic description of the region. The U.S. National Research Laboratory (NRL) salinity, temperature and roughness remote scanner (STARRS) was fitted to a Uruguayan air force aircraft and used for airborne observations of sea surface temperatures and salinities.

Two oceanographic research ships, the Argentine navy's *Puerto Deseado* and the Brazilian navy's *Antares,* were deployed during August 2003 and February 2004, respectively, to provide corresponding near and sub-surface ocean properties. Previous observations and experimental model results suggest that wind is the main forcing factor controlling excursion of the Plata plume northward.[1] River flow is the second most important factor. Since these factors vary seasonally, both winter and summertime surveys were conducted. This article describes the installation and deployment of STARRS and its application to the wintertime survey of the La Plata and Patos outflow plumes.

Airborne Salinity Mapper System

The technology for remote imaging of sea surface salinity (SSS) using microwave radiometers evolved from experiments conducted in the late 1960s.[2] Now, aircraft equipped with microwave radiometer systems can map SSS over coastal areas of about 3,000 square kilometers at a one-kilometer resolution during a four to five-hour flight.[3]

Hardware. STARRS comprises L and C-band microwave radiometers, an infrared (IR) radiometer, an integrated global positioning system (GPS) receiver and a fiber optic gyro.[4] Measurements from these instruments are combined to retrieve SSS temperature (SST) and roughness. The L-band radiometer—used primarily to retrieve salinity—is a multibeam system sens-



(Above) Interior of CASA Aviocar. STARRS electronics (left) and long-range fuel tanks (right) are located behind the life raft. STARRS radiometers are mounted on a retractable frame. The top door is lowered during flight.

(Right) Extensive SSS survey of a South American shelf from three flights conducted August 30 to September 5, 2003. Color indicates beam-averaged SSS smoothed with a five-kilometer length scale. The inset reflects an intensive survey of Patos Lagoon outflow on September 1, 2003, and Rio de La Plata estuarine front on September 10, 2003.

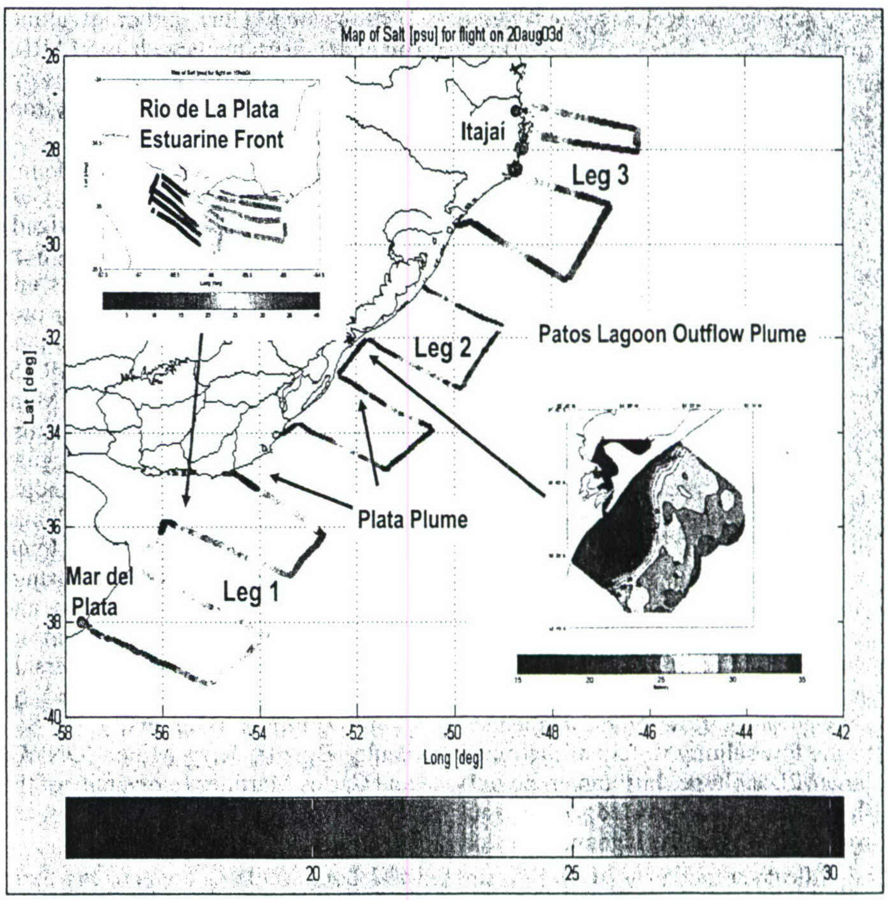
ing natural microwave emission from the sea surface within a 24-megahertz-wide protected band, centered at a frequency of 1.4 gigahertz. The six antenna beams, each with 15° half-power beam width, point downward and to either side of the aircraft at incidence angles of around 7°, 22° and 38°. The C-band radiometer, which senses surface roughness, has a single 20°-wide beam pointing directly beneath the aircraft (nadir viewing). It senses natural emission within six channels centered on 5.2, 5.6, 5.9, 6.2, 6.6 and 7.1 gigahertz. The nadir viewing IR radiometer senses SST from thermal emission in the eight to 14 and 9.6 to 11.5 micron bands. Clouds do not block the microwave observations, but do cause gaps in the IR observations, which are filled by interpolation. The GPS and gyro provide universal coordinated time, position and aircraft attitude. For parallel flight tracks, the beam geometry gives complete map coverage for typical aircraft altitudes of 2,600 meters, flight speeds of 80 meters per second and six 700 to 1,100-meter-wide beam footprints spanning a 5.2-kilometer swath.

STARRS Data Processing. The STARRS data processing system generates maps of SSS. Using STARRS C++ data acquisition software, the in-flight computer creates instrument raw data files, which are post-processed to generate files containing radiometer and merged ancillary data needed to retrieve SSS, SST and surface roughness.

These are read into NRL's custom processing system RADSYS, written using MATLAB®—from The Mathworks Inc. (Natick, Massachusetts). RADSYS edits, calibrates, filters and plots the data in time series and map formats. In map format, the actual beam footprint, sizes and positions are scaled and color-coded to visualize each swath. The irregularly spaced data may be further smoothed, gridded and contour plotted.

temperature of the sea surface, from which emissivity is determined. Emissivity is a function of seawater conductivity (itself a known function of surface temperature and salinity), the angle of view and surface roughness. After accounting for these and other geometrical and environmental influences, the relationship between salinity, temperature and brightness temperature is inverted to obtain salinity.

Adaptation of STARRS to a C-212 Aviocar. In March 2002, La Plata investigators met at the Carrasco Air Force base to discuss the technical possibilities of adapting a Seville, Spain-based Construcciones Aeronáuticas SA (CASA) Aviocar C-212 200 aircraft to carry STARRS. The adaptation was achieved by substituting an aluminum frame designed to accommodate the STARRS' radiometers for the aircraft's aft ramp. In previous adaptations, STARRS was installed below the aircraft in order to keep its radome away from interfering metal structures. However, this intro-



Principle of Operation. STARRS operation is based on the effect of salinity on conductivity and, hence, microwave emissivity of seawater. STARRS measures the physical temperature and microwave brightness

duced additional drag. In the Aviocar, only the lower three to five centimeters of STARRS projected below the airframe, with minimal impact on aircraft and instrument performance. The system used the original ramp actuators to raise STARRS during take-off and landing, and to lower it to a tilt near 0° in level flight.

A full-scale mechanical model of STARRS was constructed and flight tested in July 2003. Since aircraft performance was not significantly compromised, the team proceeded to live test STARRS to detect any electrical/electronic interference. These tests were also successful and the aircraft was certified for survey operations. Two additional fuel tanks (700 liters each) were installed, increasing duration to almost 10 hours.

Mission Plan and Logistics

The research involved two missions that were synchronized with oceanographic cruises, one in August 2003 (austral winter conditions) and a second in February 2004 (summer conditions). Two kinds of survey flight were planned: extensive and intensive. For extensive surveys, the flight altitude was 1,220 meters. The tracks covered the ship track, so near-coincident field data were obtained from the shipboard conductivity, temperature and depth profiler and surface thermosalinograph. Intensive surveys were defined over specific areas of interest in the Rio de la Plata and Patos Lagoon regions. For these, flight altitude was approximately 2,440 meters. Flight lines were also located to optimize mapping coverage.

Results

Flight data sets were processed and inter-compared with ship data. Results obtained after preprocessing and calibration revealed the main features of the SSS fields associated with the plumes. In the case of the Plata plume, its extension and surface characteristics agreed with the ship data and expected behavior in both missions. An intensive survey in summer in the Rio de la Plata revealed the front in a characteristic position within the estuary. The winter Patos Lagoon survey showed an outflow plume embedded in the low salinity waters of the much larger Plata plume. In summer, no outflow plume was detected, but a front was found inside the lagoon.

Conclusions

The STARRS radiometer system was adapted to a new aircraft platform and deployed over the South American continental shelf. The results show a capability to produce synoptic descriptions of SSS fields in continental shelf waters with a precision of approximately 0.3 practical salinity units for data with a five-kilometer spatial resolution, and detailed salinity maps of smaller coastal areas with a precision of 0.6 practical salinity units at a one-kilometer resolution. Since deployment of STARRS in South America, the instrument has been used to map the plumes of other large-scale river systems, including those of the Mississippi and Columbia Rivers in the United States.

Two satellites for mapping SSS globally, the Salinity Moisture and Ocean Salinity and Aquarius, are planned for launch in 2007 and 2009. These promise a capability to map surface salinity of the world's oceans with 0.1 practical salinity units precision at monthly intervals. STARRS airborne technology provides high-resolution (one to five-kilometer pixel size) salinity maps that can be used for satellite calibration. Beam footprints for the satellite-borne instruments are large (35 to 150 kilometers) so that they cannot adequately resolve the coastal zone. Thus, airborne salinity mapping instruments such as STARRS will continue to be needed to resolve plume features in coastal environments.

Acknowledgements

The Uruguayan air force (Brigada de Mantenimiento, Servicio de Sensores Remotos y Aeroespaciales and Escuadrón de Transporte No. 3) provided aircraft, crew and logistics, and adapted the aircraft to STARRS. Compañía Industrial de Tabacos Monte Paz SA provided additional equipment and Aluminios del Uruguay donated mounting materials. Funding was provided by the Office of Naval Research Global (ONRG), the Inter-American Institute of Global Change Research and various academic and private institutions of Argentina, Brazil and Uruguay. Project leadership and coordination was provided by Edmo Campos (University of Sao Paulo, Brazil), Jerry Miller (ONRG) and Carlos Martinez (University of the Republic, Uruguay), and they are gratefully acknowledged. /st/

References

1. Guerrero, R. A., E. M. Acha, M. B. Framinan and C. A. Lasta, "Physical Oceanography of the Rio de la Plata Estuary, Argentina," *Continental Shelf Research*, vol. 17, issue 7, pp. 727-742, 1997.
2. Burrage, D. M., M. A. Goodberlet and M. L. Heron, "Simulating Passive Microwave Radiometer Designs Using SIMULINK," *Simulation*, vol. 78, pp. 36-55, 2002.
3. Burrage, D. M., M. L. Heron, J. M. Hacker, J. L. Miller, T. C. Stieglitz, C. R. Steinberg and A. Prytz, "Structure and Influence of Tropical River Plumes in the Great Barrier Reef," *Remote Sensing of the Environment*, vol. 85, pp. 204-220, 2003.
4. Miller, J. L. and M. Goodberlet, "Development and Applications of STARRS: A Next-Generation Airborne Salinity Imager," *International Journal of Remote Sensing*, vol. 25, issues 7-8, pp. 1,319-1,324, 2004.
5. Klein, L. A. and C. T. Swift, "An Improved Model for the Dielectric Constant of Sea Water at Microwave Frequencies," *IEEE Journal of Oceanic Engineering*, vol. OE-2, no. 1, pp 104-111, 1977.

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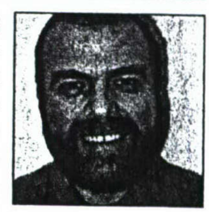

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